INVESTIGATIONS OF INDIANA LAKES

1. A Quantitative Study of the Bottom Fauna

LAKE WAWASEE (Turkey Lake)

BY

WILL SCOTT, RALPH O. HILE,
and HERMAN T. SPIETH

THE DEPARTMENT OF CONSERVATION
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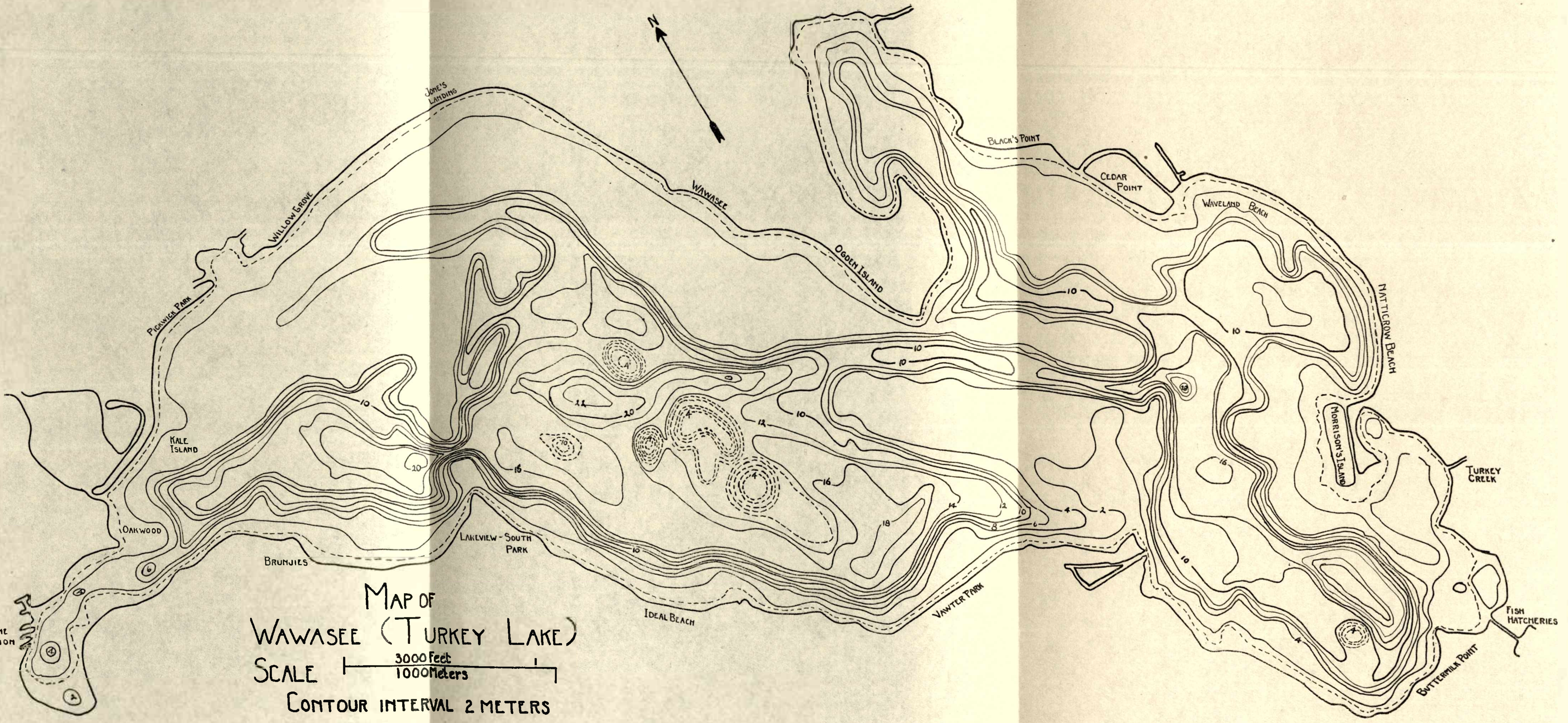
Map of
Wawasee (Turkey Lake)
Scale
3000 Feet
1000 Meters
Contour interval 2 meters
N
Jone's Landing
Willow Grove
Pickwick Park
Kale Island
Oakwood
Marine Station
Brunjies
Lakeview-South Park
Ideal Beach
Vawter Park
Wawasee
Ogden Island
Black's Point
Cedar Point
Waveland Beach
Natticrow Beach
Morrison's Island
Turkey Creek
Fish Hatcheries
Buttermilk Point

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I. A Quantitative Study of the Bottom Fauna of Lake Wawasee (Turkey Lake)

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Will Scott, Ralph O. Hile, and Herman T. Spieth

In cooperation with

THE DIVISION OF FISH AND GAME

of the

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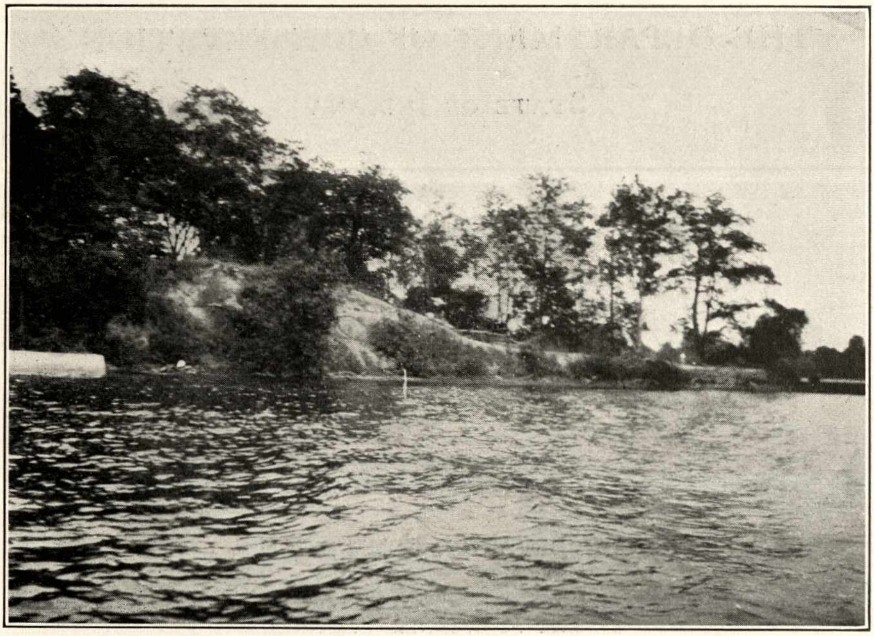

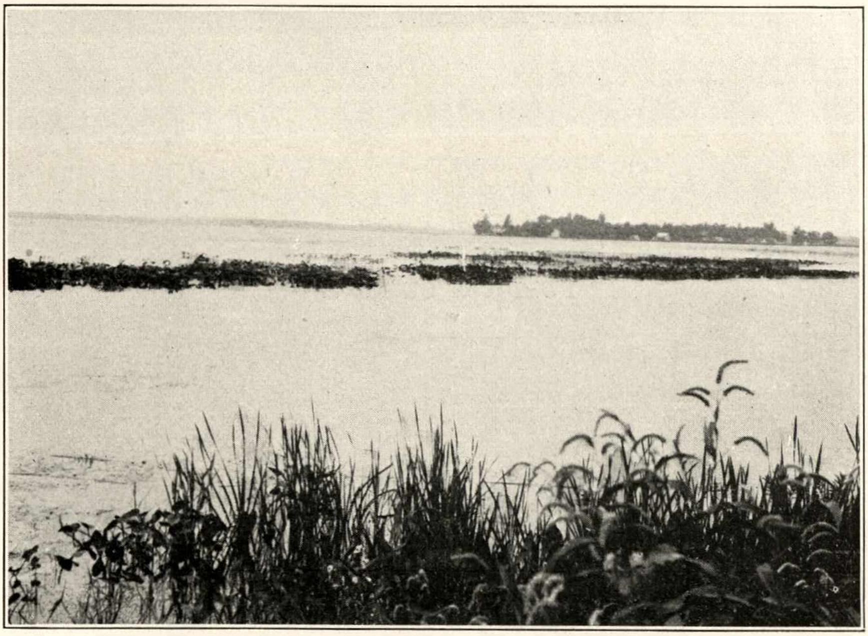

PLATE I. A. Cedar Point, one of the promontories having rapid wave erosion and few plants.
B. Hatcheries Bay, no erosion and many plants.

INTRODUCTION

Early in 1926 the Superintendent of the Division of Fish and Game of the Indiana Department of Conservation and the Director of the Indiana University Biological Station agreed to cooperate in the investigations of the lakes of Indiana, giving especial attention to the fundamental problems related to the fisheries. The Division of Fish and Game pays the field expenses and publishes the results. The University furnishes the apparatus, the men to do the field work, and laboratory facilities for working up the material.

The problem attacked is the productivity of our lakes and the factors that influence it. Studies on other lakes indicate that fishes grow more rapidly in one habitat than in another. The age and consequently the rate of growth of most of our fishes can be determined with considerable accuracy by a study of their scales.

It is planned to estimate as accurately as possible the number of organisms present in a series of lakes and the amount of organic material they contain that is available for fish food. Correlated with this a study is being made of the rate of growth of the fishes in these lakes.

Lake Wawasee (Turkey Lake) was investigated first and the data on this lake form the basis of this report. This lake was selected for two reasons. It is the largest lake in the state and on it the Division of Fish and Game has a hatchery, whose facilities were made available for the field work.

Two summers have been devoted chiefly to the study of the bottom fauna of the lake. The first (1926) was devoted to the littoral (shore) forms out to a depth of two meters. During the second season the deep water organisms were studied. Some preliminary work was done on the dissolved gases and plankton.

The junior authors are responsible for the collecting and counting. The senior author planned the work, supervised its execution, did the weighing, aided in the identification of organisms, and has done most of the subsequent work on the material. Mr. Spieth prepared the map and Mr. Hile has done most of the computing on the morphometry of the lake. The work on fish scales is wholly the work of Mr. Hile. The three of us have conferred at every point in the study and share responsibility for the general results.

The Lake

Location

Lake Wawasee (Turkey Lake) is located in Kosciusko County, Indiana. It lies in sections 8, 9, 10, 11, 13, 14, 15, 16, 17, 22, 23, 24, 25, and 26 R.7E., T.34N. Almost all of section 15 lies in the lake. Of all the sections forming part of the lake this has the maximum water area.

The lake includes the intersection of parallel 41° 31′ N. Lat. and the meridian 88° 44′ W. Long.

The waters of this lake are a part of the St. Lawrence drainage basin, and are carried through Turkey Creek, Elkhart River, and St. Joseph River to Lake Michigan. It lies near the western edge of the Saginaw Huron-Erie

interlobate moraine. Two miles south of the lake occurs an undissected part of this moraine which forms a part of the continental divide separating the drainage of the St. Lawrence and the Mississippi. Webster Lake, four miles south of Lake Wawasee (Turkey Lake), discharges its water to the Mississippi through Grassy Greek, Tippecanoe Lake, Tippecanoe River, Wabash River, and Ohio River.

Dimensions

The longest axis of the lake is approximately N.W. to S.E. Its greatest length taken as the maximum distance between parallel lines tangent to the lake shore is 22,700 ft. (6,920 m.) or 4.29 miles. Taking the maximum length as the longest mid-channel line, that is, a line from the hatcheries bay to the bay at the west end of the lake, it is 25,300 ft. (7,713 m.) or 4.79 miles.

Considering the first as the maximum length the average width is 5,559 ft. (1,695 m.) or 1.05 miles. If the mid-channel line is considered the maximum length, the average width is 4,982 ft. (1,519 m.) or .94 miles. The greatest length of open water on a straight line is 21,400 ft. (6,920 m.) or 4.05 miles.

The shore line is 15.73 miles (25.33 kilometers) in length.

Form

The determination of the form of a lake is basic to any study of its physical and chemical characteristics or to any quantitative study of the organisms living in it. Not only its outline but depth, areas of various depths and volume must be known. To determine these facts a metric map was constructed based on soundings made by Dr. W. M. Tucker and kindly supplied by him. Certain minor corrections have been incorporated in the map. The metric system has been used in order that these results may be more easily compared with the results obtained on the other lakes of the world.

The general form or contour of the lake can be seen most easily by consulting the map. There are three rather distinct basins, one in the S.E. or hatcheries bay, one toward the west end and a larger and more irregular basin occupying the central portion of the lake.

The east and west basins each reach a depth of 20 meters (66 ft.). The central basin has a maximum depth of 23 meters (76 ft.).

The eastern depth is connected with the central one by a channel which at its narrowest point south of "Ogden's Island," is 140 meters (460 ft.) wide between the 4 meter contours. The depth of this channel is near 10 meters. The channel connecting the west basin with the central one is narrower but reaches a maximum depth of slightly more than 14 meters.

The central basin is not only irregular in outline but contains five shallows where the bottom rises rather rapidly to within four meters (or less) of the surface. Three of these are near each other and separated from the other two by the sixteen meter contour.

Johnson's Bay forms a shallower basin. The eight meter contour encloses quite an area in this bay but the ten meter contour barely reaches the entrance. In the three major basins the oxygen is exhausted from the lower levels but in Johnson's Bay there is a rather large amount of oxygen to the very bottom in spite of the fact that the bottom here is covered with rich

organic debris. It appears from the temperature readings that when the wind sets in from the southeast the water piles up in this bay and forces the bottom water toward the deeper water to the southeast.

Slope

The slope has been computed in per cents, which is another way of saying that it is the average difference in depth in feet for each hundred feet from the shore toward the deeper part of the lake.

The formula used is appended at the end of the paper. The slope between two contours is another way of expressing the distance between them. If the average distance between them is short the slope is steep. It is, of course, related to the area between the contours, and the length of the contours; the longer the contours with a given area the steeper the slope and conversely the greater the area between contours of a given length the more gentle the slope. It will appear that slope is a very important factor in the economy of this lake.

In about twenty other Indiana lakes that have been examined, the slope is less from the shore to the 2 meter contour (S-2) than at any other level. In Lake Wawasee (Turkey Lake) however, this region has a slightly steeper slope than the area between 2m.-4m. contours. The S-2m. slope is 2.42 while the 2m.-4m. slope is only 1.45. Not only is the 2m.-4m. level one of gentle slope but it contains 923 acres or nearly one-third (32.1 per cent) the area of the entire lake. This means that 923 acres of this lake are between 2 meters and 4 meters in depth and slopes on an average less than 1½ feet to the hundred. The data indicate also that this is a very productive area. Fifty-one and nine-tenths (51.9) per cent are less than four meters in depth.

From the depth of four meters, the slope becomes relatively steep until a depth of 8 meters is reached when it again becomes more gentle. The slope from four to six meters is 9.01 and from six to eight meters is 11.84 per cent. The areas contained are 6 per cent and 5.1 per cent, respectively, of the entire lake. To put this graphically, the maximum grade allowed on a federal aid highway is seven per cent. The average slope in this lake between six and eight meters is one and sixty-nine hundredths times this maximum.

The average slope for the whole lake is 4.01. The areas between slopes, the slopes in per cents for each level, and the per cent of the total area included between successive contours are given in Table No. 1.

Volume

The volume of the lake has no very direct relation to the bottom fauna but where the plankton is studied its significance is apparent. While 51 per cent of the area of the lake is above the 4 meter level, slightly less than one-half, 47 per cent of the volume lies above this depth. The ten meter level has 83.5 per cent of the water of the lake above it and 16.5 per cent below it. It is evident that the plankton of the upper levels is the more important. See Table No. 2.

The Collections

Littoral

The lake was divided into littoral and deep water areas at the 2 meter contour. This was done simply for convenience in collecting. In the shallower

water (out to 2 meters) more accurate samples could be obtained with the hoe dredge while beyond this depth the Ekman dredge was used. The summer of 1926 was devoted to the study of the littoral. Two series of collections were made along the shore line. Each series required about six weeks to complete. The fauna changes during the season and it is desirable to complete the series in as short a time as possible. Any method must be a compromise and the plan used is good in that it gives an early summer and a later summer picture.

The littoral stations were spaced according to variations in the habitat rather than equidistant. The stations of the second series alternated with the stations of the first series. Each station was regarded as typical for a definite area.

This area was determined by bisecting the distance between two stations. The area enclosed by the two bisecting lines, the shore, and the 2 meter contours were assigned to the contained station. The areas were determined separately with a planimeter. See Plate No. 5.

It was assumed that the fauna was distributed evenly over each station area. The fauna at each station was determined by averaging collections at four depths, .5m., .75m., 1.m. and 1.25m. The totals were determined by adding the products obtained by multiplying the average per square meter for each station by the number of square meters in it.

The collections were made with two instruments of our own construction. They are the hoe dredge and the sample cutter. The latter is a heavy sheet metal frame 2 dm. by 5 dm. inside measurement. It is open above and below. On the sides and one end it is 12 cm. high with a flange on the upper edge bent outward at right angles. The other end is 6 cm. high with no flange. The flange is merely to stiffen the instrument and to furnish a surface for forcing it into the lake bottom. When forced into the lake bottom, the low end has its upper edge 6 cm. below the soil surface. Into the cut made by this end, the hoe dredge is introduced and drawn to the opposite end of the cutter. When starting the dredge, the handle is at as low an angle to the horizontal as the depth of the water will permit. As the sample is taken it is raised gradually to the vertical. See Plate No. 2.

The hoe dredge is made of 20 or 16 gauge metal shaped like a box with two opposite sides out. It is 2 dm. wide outside measurement and 12 cm. high. In the center of one of the long sides is riveted a base such as is used in fastening iron pipes to floors or other surfaces. A socket with suitable handle screws into this base. On the upper edge of each side a flange is bent outward at right angles. Over this flange a bag is attached with a draw-string.

The sample cutter is ground to a cutting edge with a bevel on the outside while the dredge is ground to a cutting edge with a bevel on the inside.

Samples taken with these two instruments are of rather precise dimensions. These samples can be cut from bottom covered with Chara or other prostrate plants. Where the plants are extremely thick, a dredge with a larger opening is required. However, the dimensions given are satisfactory in our lakes.

After a sample is taken it is washed in a net made of number 40 grit gauze. The one used is 40 cm. deep and hung on a triangular frame whose sides measured 30 cm. The washing can be done best by immersing the

lower two-thirds of the bag in the water and alternately raising and lowering the bottom of the bag with the hand. This removes all the fine detritus and marl with minimum injury to the contained organisms. The residue is then placed in buckets and taken to shore for counting. Each form was identified and counted separately. The totals together with depth, temperature, and other physical data are entered on a card.

The weight of the more important organisms were determined. To do this, samples of each organism were counted into a dish containing a small amount of water. After being counted they were placed on a piece of wet bolting silk stretched over the large end of a funnel. By tilting this funnel the excess water was removed. The sample was then placed in a platinum foil dish and weighed on an assay balance sensitive .01 mg. This was recorded as wet weight (W.W.). It was then dried to a constant weight in an electric oven at a temperature of 60°C. The dry weight (D.W.) was then determined. The sample was ashed in an electric furnace at approximately 550°C. The weight of the ash subtracted from the dry weight is regarded as the amount of dry organic matter (D.O.M.) present.

The numbers upon which the average weights of the organisms were determined varied with the size of the organism from four in the case of the odonata to 1,595 in the case of the amphipoda.

Deep Water

The collections in deep water were made on the odd contours from the 3 meter contour on one side of the lake to the three meter contour on the opposite side. Twenty such series were made. The average for all the collections at a given depth was taken as the average for the area enclosed by the adjacent contours. For instance the average of all the collections made at 5 meters was taken as the average for the area between the 4 and 6 meter contours. The number of collections at each depth and the average number of organisms per square meter in each area are given in Table No. 4.

The collections were made with a 6 inch Foerst-Ekman dredge. Two catches were made at each station and averaged. The reduction of the sample with a grit gauze net; the enumeration and record of organisms were made as in the littoral.

This lake, as already indicated, differs from the other Indiana lakes so far examined in the relative slope and area of the S-2 and 2-4 meter regions. In this lake the former has a slope of 2.42 and an area of 568 acres while the 2-4 meter region has a slope of 1.45 and an area of 928 acres. This is due to the larger size of Lake Wawasee (Turkey Lake). The rachion, or wave line, of Muttkowski ('18) is included in the S-2 region.

A study of the material from the deep water indicated that the 2-4 area was distinct from the 4-bottom and hence the results have been grouped in the three levels, S-2, 2-4, and 4-bottom. The areas of these levels are 568, 923, and 1376 acres, respectively.

The S-2 region is exposed to waves and shore currents. Part of it is rather barren sand and marl. Part is covered with chara and at some points it is invaded by the rushes and Potamogeton of the deeper water. In this paper it is designated as the "open littoral."

The 2-4 region is very generally covered with the submerged aquatic phanerogams, most of which are Potamogetons. It is a very productive area of

the lake even when the plants are omitted, although certain forms like the sphaeriidae seem to avoid it. This we call the "weedy littoral."

The area beyond the 4m. contour is called simply "deep."

The Fauna

Quantitative Results

The results are apparent from an inspection of Tables Nos. 4, 6, and 7.

Annelids

These small aquatic worms do not make a large aggregate but they are very generally distributed and form a part of the diet of all small fish. The littoral contains slightly more than the deeper parts of the lake. Table 4 indicates that they are rather irregularly distributed although part of this may be due to errors in counting. They have a habit of balling up in more or less spherical masses so that precise counting is difficult.

Insect Larvae

In the open littoral (S-2m.) the three important groups are the ephemerid (May fly) nymphs, the odonata (dragonfly) nymphs and the chironomid (midge) larvae (sens. lat.) other than Chironomus tentans. The wet weight of the chironomids and ephemerids is 28.68 and 28.36 lbs. per acre, respectively. The weight of the odonata nymphs is 6.68 lbs. per acre. The total weight for the insect larvae in this region is 63.72 lbs. per acre.

In the weedy littoral (2m.-4m.) the chironomids are reduced to 11.51 lbs. per A., the ephemerids are negligible (.34) and the odonata are represented by a few damsel fly (anisoptera) nymphs. However, the orl fly (Sialis) has become an important element (10.36).

The most important element of the bottom insect fauna of the deep area (4m.-3m.) is the large blood worm, the larva of chironomus. The weights are based on a sample of 100 large specimens collected August 7. The totals represent more nearly the maximum than the average for the summer. Based upon this weighing they amount to 326 lbs. per acre in the deep area and about 4½ lbs. for the 2m.-4m. level.

They seem to reach a rather definite maximum at 15 meters where there are 881 per square meter. See Table No. 4. The other chironomids amount to slightly more than half (6.38) those of the weedy littoral. Sialis increases to 12.34. The total weight in lbs. per A. of insect larvae in the three depths is 63.72, 26.78, and 348.98, respectively.

The Crustacea

The important bottom crustacea are the crayfish (Cambarus) and the amphipods or scuds (Hyalella and Eucrangonyx). Both of these are important out to about 6 meters and are of especial significance in the open littoral and the weedy littoral.

In the open littoral (S-2) the number of crayfish is greater than our data indicate. The water was clear and some escaped. This was especially true for the larger ones. The crayfish taken were all near the same size, their length being between 2 and 3 inches. It was assumed that they were in their second year although there is no evidence for this assumption other than this uniformity in size.

The total weight of the crayfish in both the open littoral (S-2) and the

weedy littoral (2-4) exceed that of the amphipoda, the weights being 23.41 lbs. per A. and 110.22 lbs. per A., respectively, for the crayfish and 18.05 and 14.25 for the amphipoda. However, this does not represent the true value of the two forms because the amphipoda produce a brood about every twenty-five days while the crayfish breeds once a year.

The Gastropoda (Snails)

On the whole this group is of more importance in the open littoral and weedy littoral than in the deeper water. Goniobasis, Physa, and Amnicola are strictly littoral forms. However, Planorbis reaches its maximum at 5m. and Valvata at 9 meters.

Goniobasis is the most important member of this group. It forms by weight 97 per cent of all the snails in the open littoral and 74 per cent of all snails in the weedy littoral. The lower per cent of Goniobasis in the weedy littoral is due largely to the increase in Physa which reaches 90 lbs. per acre in this area.

Amnicola is the most evenly distributed in the inshore areas. It is between 4 and 5 lbs. per acre in both the open and weedy littoral.

Planorbis has a rather general distribution reaching a maximum of 4.69 lbs. per acre in the weedy littoral, its ratios in the three areas being approximately 2-6-3.

The Sphaeriidae

These little bivalves are found everywhere in the lake bottom. Sphaerium reaches a very definite maximum at 9 meters. Pisidium on the other hand has a decided preference for deep water. It increases directly with the depth until 11 meters is reached, beyond which it remains fairly constant. See Table No. 4.

On account of its greater size, the total weights of Sphaerium for all three areas is greater than those of Pisidium.

One very interesting fact is shown in Table No. 7. It is that both forms are more numerous in the open littoral and deep water area than in the weedy littoral. In both forms the proportions for the open littoral (S-2), weedy littoral (2-4), and deep littoral (4-22) areas are very close to 6-1-20. The only factor that we have been able to associate with the reduced number in the weedy littoral is the increased number of submerged phanerogams chiefly Potamogetons. Why such a relation should exist is not apparent.

Adding the totals in Table No. 7 gives the number of invertebrates on the bottom of Lake Wawasee (Turkey Lake). This number is slightly more than 18 billion.

The wet weight of these obtained by multiplying the total of all forms in lbs. per acre in each area by the number of acres (as indicated in Table No. 6) gives a total wet weight of 2,028,961 lbs. The dry organic matter averages about 9 per cent of this total, which is 182,606 lbs. These numbers are not the absolute facts but they are as close an approximation as is practicable. They are based on two years' collections. Their accuracy can only be increased by increasing the amount of data. The increase in accuracy, however, is not directly proportional to the increase in data. The accuracy of these two years' work would not be doubled by working four years but would require eight years by the well known formula $2 \times 2^2 = 8$. To treble it would require $2 \times 3^2 = 18$ years.

Other work on related lines is regarded as more profitable.

A general discussion of these results, their relation to the problem of the turnover, to fisheries, and to previous work in this field is reserved for the second section of this paper.

Some notion of the work already done on bottom fauna may be obtained by consulting the text and bibliography of Ekman '17, Juday '22, and Adamstone and Harness '23.

Lists of Species:

Specific names have not been used in the body of this paper. They have no particular bearing on the problem in hand and furthermore specific determinations cannot be made in most instances when handling large numbers daily even if the worker were qualified.

Precise determination of species is of great value in the study of distribution; while a mistaken identification only adds to the confusion. The following organisms have been identified or reviewed by the authorities indicated and to whom acknowledgment is hereby made. It is hoped to increase these lists of authoritatively determined material.

Hirudinea (Leeches), identified by Professor J. Percy Moore of the University of Pennsylvania:

Glossiphonia (Helebdella) stagnalis
Glossiphonia nepheloidea
Glossiphonia fusca
Glossiphonia complanata
Glossiphonia heteroclita
Nephelopsis obscura

Hydracarina (mites), identified by Dr. Ruth Marshall, Rockford College:

Name	Depth in Meters	Date	Sta. No.
Limnochares aquaticus (L.), cosmopolitan common	.5	Aug. 10	87
Limnesia nymph, undetermined	1.	Aug. 7	85
Lebertia porosa Thor, cosmopolitan common	1.	Aug. 7	85
Lebertia porosa Thor	.5	Aug. 3	81
Lebertia porosa Thor	.5	Aug. 7	85
Unionicola crassipes (Müll.), cosmopolitan common	.5	Aug. 3	81
Hygrobates undeterm. (Nov. spec.?)	1.	Aug. 7	85
Albia undeterm. (Nov. spec.?), not common	.5	Aug. 10	87
Atractides parviscutus Mar., common	1.5	Aug. 7	85
Atractides parviscutus Mar.	.5	Aug. 10	87
Atractides parviscutus Mar.	1.	Aug. 7	85
Piona reighardi (Wol.), very common	1.	Aug. 7	85
Piona reighardi (Wol.)	.5	Aug. 10	87
Arrhenurus megalurus Mar., very common	1.5	Aug. 7	85
Arrhenurus manubriator Mar., common	.5	Aug. 3	81
Arrhenurus americanus Mar., very common	.5	Aug. 10	87
Arrhenurus pseudocylindratus Piers., not common	1.	Aug. 7	85
Arrhenurus fem. unid	1.5	Aug. 7	85
Arrhenurus fem. unid	1.	Aug. 3	81
Arrhenurus fem. unid	1.	Aug. 7	85

Name	Depth in Meters	Date	Sta. No.
Arrhenurus fem. unid.	.5	Aug. 10	87
Arrhenurus nym. unid.	.5	Aug. 10	87

Crustacea. Amphipoda (scuds), identified by Mr. C. R. Shoemaker of the United States National Museum:

Eucrangonyx gracilis (Smith)
Wawasee Lake, Ind. 6-22-1926
Hyalella azteca (Saussure)
7-24-1926

Gastropoda (snails) and Sphaeriidae (small bivalves), identified by Mr. Herman P. Wright, Indiana University:

LYMNAEIDAE
Lymnaea danielsi Baker

PLANORBIDAE
Planorbis antrosus Conrad
Planorbis campanulatus Say
Planorbis exacuous Say
Planorbis exacuous megas Dall
Planorbis parvus Say
Planorbis deflectus Say

PHYSIDAE
Physa integra, var.
Physa sayii, var.

VIVIPARIDAE
Campeloma rufum (Haldeman)

VALVATIDAE
Valvata bicarinata Lea
Valvata bicarinata normalis Walker

AMNICOLIDAE
Amnicola lustrica Pilsbry
Amnicola limosa porata (Say)
Amnicola walkeri Pilsbry
Amnicola pilsbryi Walker

PLEUROCERIDAE
Goniobasis livescens Menke

SPHAERIIDAE
Sphaerium acuminatum Prime
Sphaerium sulcatum Lamarck
Sphaerium rhomboideum Say
Pisidium compressum Prime
Pisidium fallax Sterki
Pisidium variable Prime
Pisidium scutellatum Sterki

Pisidium adamsi Prime
Pisidium medianum Sterki
Pisidium minutum Sterki
Pisidium tenuissimum Sterki
Pisidium concinnulum Sterki
Pisidium vesiculare Sterki
Pisidium superius Sterki
Musculium declive Sterki
Musculium sp.

Formula used in calculating slope:

$$S = \frac{C_1 + C_2}{2} \cdot \frac{I}{A}$$

Where S is the slope between two contours, C_1 and C_2 are the length of the contours, I is the contour interval and A is the area between the contours.

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D	Length of Contour	Area Between Contours sq. m.	% of Total	Slope
S	25,335	2,301,886	19.8	2.42
2	25,335	3,736,669	32.1	1.45
4	30,732	705,719	6.0	9.01
6	31,493	597,176	5.1	11.84
8	30,792	1,005,462	8.6	5.49
10	25,609	1,026,580	8.8	4.00
12	15,512	698,074	6.0	4.46
14	15,658	801,319	6.9	3.22
16	10,121	566,956	4.8	2.63
18	4,817	84,472	.7	8.30
20	2,195	69,202	.5	3.81
22	439	15,253	.1	2.16
		11,608,768		

TABLE NO. 1. Area and slope data for the different levels of the lake.

Depth	Vol. Each Level	% Total	R. T.
S-2	21,336,414	27.4	1.83
2-4	15,249,929	19.6	1.32
4-6	10,852,597	13.9	.93
6-8	9,639,360	12.3	.83
8-10	8,070,108	10.3	.69
10-12	5,462,381	7.0	.47
12-14	3,750,775	4.8	.32
14-16	2,224,440	2.8	.19
16-18	838,191	1.0	.07
18-20	248,556	.3	.021
20-22	90,372	.1	.007
22-	7,628		
	77,770,751	99.5	

TABLE NO. 2. Distribution of volumes. The second column is percent of totals and the third is the reduced thickness. The average depth is 6.69 meters or 21 ft. The "reduced thickness" is the depth that level would have if it had an area equal to that of the lake surface and sides vertical. The sum of the R. T. equals the average.

Name of Form	Number per Station		Station Number of Max.	Total
	Avg. Sq. M.	Max. Sq. M.		
Platyhelminthes—				
Turbellaria (flat worms)	36.7	477	93	76,807,200
Annelida—				
Oligochaeta	26.7	145	69	56,073,900
Hirudinea (leeches)	44.4	457	83	93,097,000
Crustacea—				
Isopoda	40.9	2,390	33	278,192,000
Amphipoda (scuds)	1,463.7	5,505	88	3,063,588,000
Cambarus (crawfish)	5.2	20	61	11,031,800
Insecta—				
Ephemerida	152.2	1,390	109	318,971,000
Tricoptera	42.2	297	85	89,992,000
Odonata—				
Anisoptera	2.0	20	88	2,589,800
Zygoptera	1.2	27	83	641,008,000
Coleoptera—				
Imagoes	3.0	22	93	6,470,000
Larvae	6.1	37	43	12,802,600
Chironomus	306.3	1,932	87	641,008,000
Snails—				
Physa	29.7	675	85	62,202,000
Goniobasis	83.4	427	112	174,601,000
Amnicola	29.5	507	63	61,882,000
Planorbis	4.5	32	88	9,547,000
Valvata	.04	2	59	86,700
Lymnea	1.3	3	74	2,727,000
Campeloma	.04	2	59	86,700
Lamellabranchiata—				
Pisidium	8.7	130	92	51,958,900
Sphaerium	33.0	1,375	49	69,175,300
Total				5,723,897,900

TABLE NO. 3. In the first column is given the average number per square meter, in the second column the maximum per square meter, in the third column the number of the littoral station where the maximum occurs and in the last column the total number in the littoral region.

All these maxima occurred in the second series except those for the oligochaeta, isopoda and Pisidium.

No. Collections	42	47	46	44	38	37	30	21	24	8	2
Depth	3	5	7	9	11	13	15	17	19	21	23
Turbellaria	14.15	5.70	.93	.48	.56	......	......	......	......	......	......
Oligochaeta	10.35	5.49	3.29	6.84	13.59	25.00	32.28	14.34	76.76	......	......
Hirudinea	28.18	20.14	6.08	2.93	2.83	.58	.71	1.02	......	......	......
Sphaerium	2.56	27.93	55.20	116.40	91.74	45.09	28.69	18.44	8.06	5.38	......
Pisidium	4.09	7.32	14.97	41.57	117.79	133.77	116.92	115.79	110.29	149.12	......
Planorbis	13.83	32.50	30.40	10.27	2.22	......	......	1.02	......	......	......
Goniobasis	71.73	17.39	2.10	.97	......	......	......	......	......	......	......
Valvata	9.22	6.86	10.05	14.18	19.25	5.15	3.60	......	1.79	......	......
Physa	79.92	63.18	11.69	.48	.56	......	.71	......	......	......	......
Amnicola	67.12	53.11	13.09	4.89	1.69	.58	1.45	......	......	......	......
Campeloma	1.02	......	.46	......	......	......	......	......	......	......	......
Amphipoda	1,005.54	255.95	25.98	.48	......	......	......	......	......	......	......
Isopoda	127.85	43.74	28.52	1.46	.56	......	......	......	......	......	......
Cambarus (crawfish)	22.54	13.27	4.67	.97	......	......	......	......	......	......	......
Chironomus tentans	7.17	43.96	97.77	300.78	720.92	825.90	881.80	603.58	202.64	306.66	150.04
Other Chironomidae	161.91	59.52	70.17	96.84	122.89	97.71	61.69	106.50	78.01	88.77	118.86
Corethra	1.53	91	9.35	18.26	62.86	211.71	223.09	189.58	247.84	290.52	225.96
Other diptera	13.17	9.15	5.61	7.33	5.09	2.87	1.43	2.04	......	......	......
Ephemeridae	75.83	42.12	24.79	7.33	1.69	.58	......	......	......	......	......
Sialis	16.87	6.27	36.72	45.74	29.43	10.46	1.43	1.02	......	......	......
Damsel fly	4.61	.45	......	......	......	......	......	......	......	......	......
Tricoptera	17.94	4.10	2.10	.48	......	......	......	......	......	......	......

TABLE NO. 4. Distribution with reference to depth of the various "deep" water organisms. Average number per square meter.

Name	Number Weighed	W. W.	D. W.	Ash	D. O. M.
Turbellaria	114	.1876	.0526	.0316	.021
Oligochaeta	454	1.5923	......	......	.1854
Isopoda	309	.5946	.2331	.0662	.0427
Amphipoda	1,595	2.5333	.2331	.0662	.1669
Cambarus	6	3.2878	.3433	.1905	.1528
Ephemerida	86	.1906	.0188	.0030	.0158
Odonata	4	.6303	.10353	.02846	.07407
Sialis	4	.276	.0403	.0027	.0376
Chironomus tentans	100	7.0088	.4346	.0651	.3735
Other Chironomidae	531	4.2341	.5004	.1179	.3835
Corethra	274	1.1099	.0779	.0063	.0716
Amnicola	24	.1977	.069	.0421	.0169
Physa	7	.8918	.2102	.1551	.0551
Goniobasis	10	4.7512	2.6368	2.3685	.2683
Valvata	20	.5617	.1879	.1222	.0657
Planorbis	34	1.2932	.4023	.3153	.087
Sphaerium	9	4.0022	1.0742	.9106	.1636
Pisidium	50	.8848	.4159	.2848	.1311

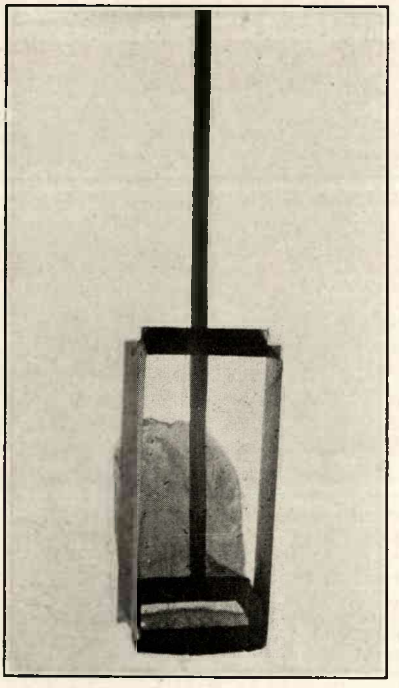
TABLE No. 5. Weight in grams of the various organisms and the number of each weighed. W. W. = Wet Weight. D. W. = Dry Weight. D. O. M. = Dry Organic Matter that is D. W. minus ash.

Description of Areas	Open Littoral	Weedy Littoral	Deep
Area in Acres	568	923	1,376
Depths	S.-2 m.	2 m.-4 m.	4 m.-23 m.
Annelida	.59	.49	.47
Isopoda	.94	2.17	.16
Amphipoda	18.05	14.25	.50
Cambarus	23.41	110.22	11.22
Total Crustacea	42.40	116.64	12.18
Ephemerida	28.36	.34	.96
Odonata	6.68		
Sialis		10.36	12.34
Chironomus tentans		4.48	326.24
Other Chironomidae	28.68	11.51	6.38
Corethra		.09	3.06
Total insect larvae	63.72	26.78	348.98
Amnicola	4.12	4.93	.70
Physa	2.32	90.87	10.74
Goniobasis	334.59	304.16	11.03
Planorbis	1.41	4.69	2.37
Total gasteropoda (snails)	342.44	406.96	27.41
Pisidium	3.70	.64	12.73
Sphaerium	62.74	10.25	235.01
Total Sphaeriidae	66.44	10.89	277.74
Total all forms per A	515.56	561.76	666.78

TABLE NO. 6. Wet weight (W. W.) of the important organisms in pounds per acre for the three major areas of the lake, the open littoral (S-2m.), the weedy littoral (2m.-4m.) and the deep (4m.-23m.).
Multiplying any of the above numbers by the factor 1.11 will give approximately the number of kilos per hectare.

Area in Acres	568	923	1,376
Description	Open Littoral	Weedy Littoral	Deep
Depth	S-2 m.	2 m.-4 m.	4 m.-23 m.
Turbellaria	76,807	52,873	5,635
Oligochaeta	56,073	59,354	85,317
Hirudinea	93,097	105,299	25,135
Isopoda	278,192	477,733	59,740
Amphipoda	3,063,588	3,757,370	96,574
Cambarus	11,031	84,224	13,127
Ephemerida	318,971	283,351	54,035
Odonata	643,597	17,226	317
Sialis		63,037	111,629
Chironomus tentans		26,791	2,905,273
Other chironomidae	641,008	605,004	499,996
Corethra		5,717	441,108
Amnicola	61,882	250,805	53,512
Physa	62,202	298,634	52,653
Goniobasis	174,601	268,031	14,501
Planorbis	9,547	51,678	53,694
Valvata	86	34,452	51,339
Lymnea	2,727		
Campeloma	86		
Pisidium	51,958	15,282	329,858
Sphaerium	69,175	9,565	29,858

TABLE NO. 7. Total numbers in thousands in the three areas of the lake.



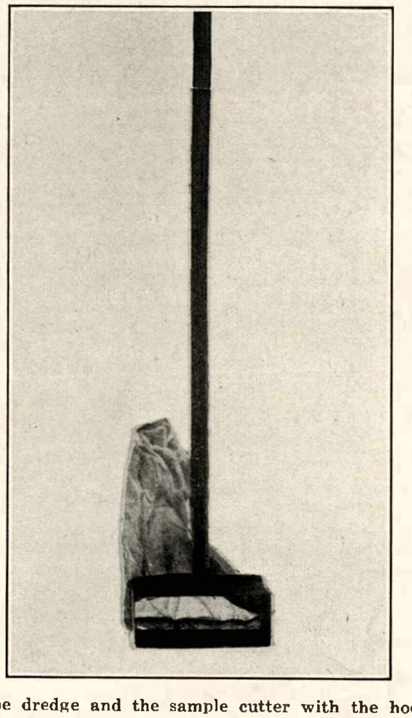


PLATE II. The hoe dredge and the sample cutter with the hoe dredge in place.

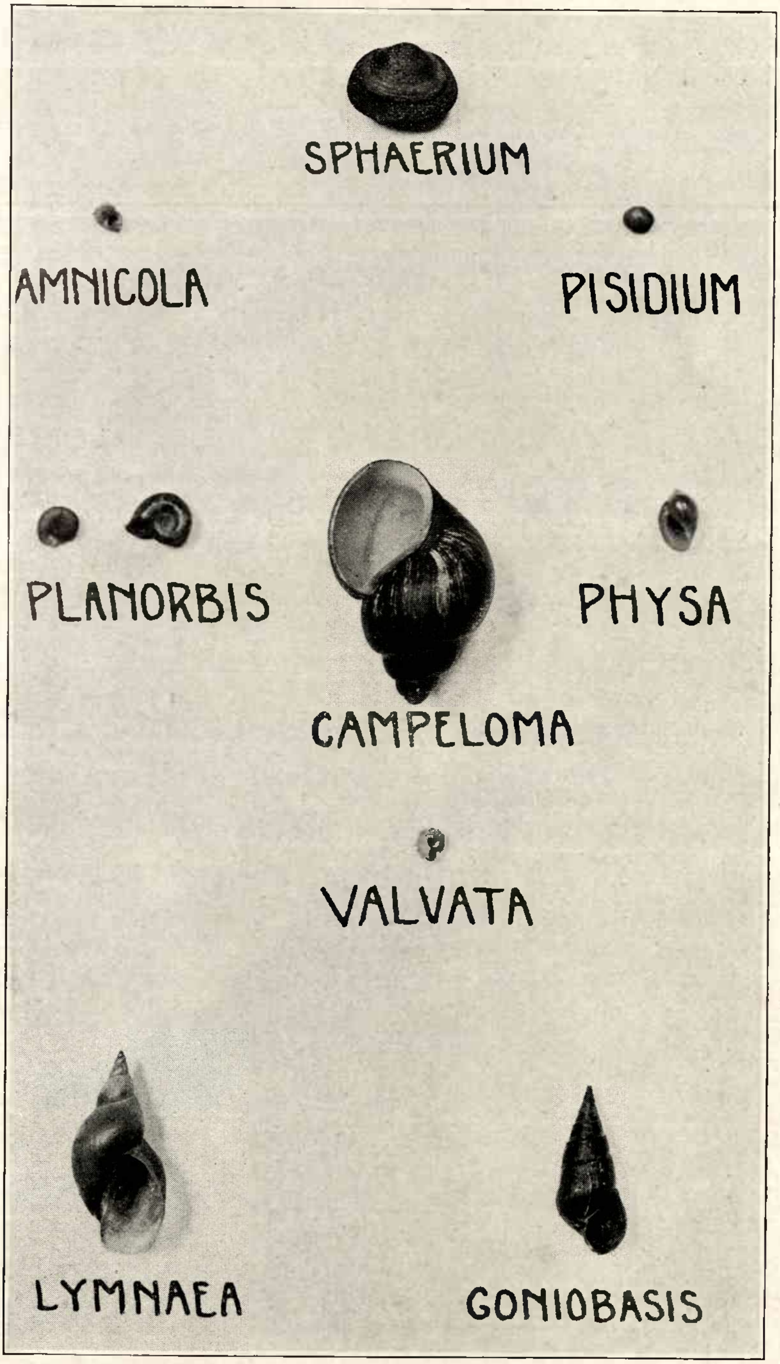
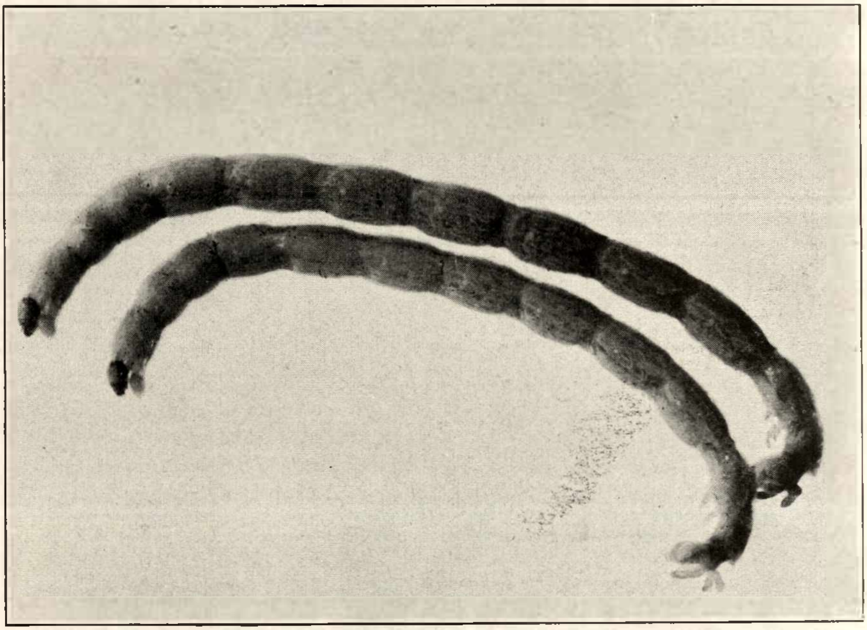


PLATE III. Some of the common genera of littoral gastropods (snails) and the two bivalves Sphaerium and Pisidium.



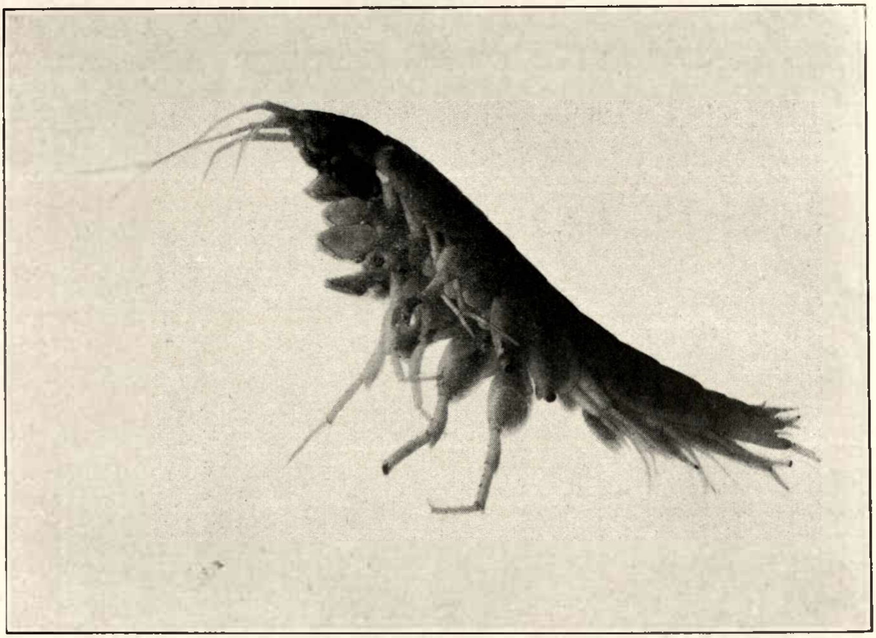


PLATE IV. Two of the important bottom forms, the large blood worm (Chironomus tentans) and the amphipod or scud (Eucrangonyx).

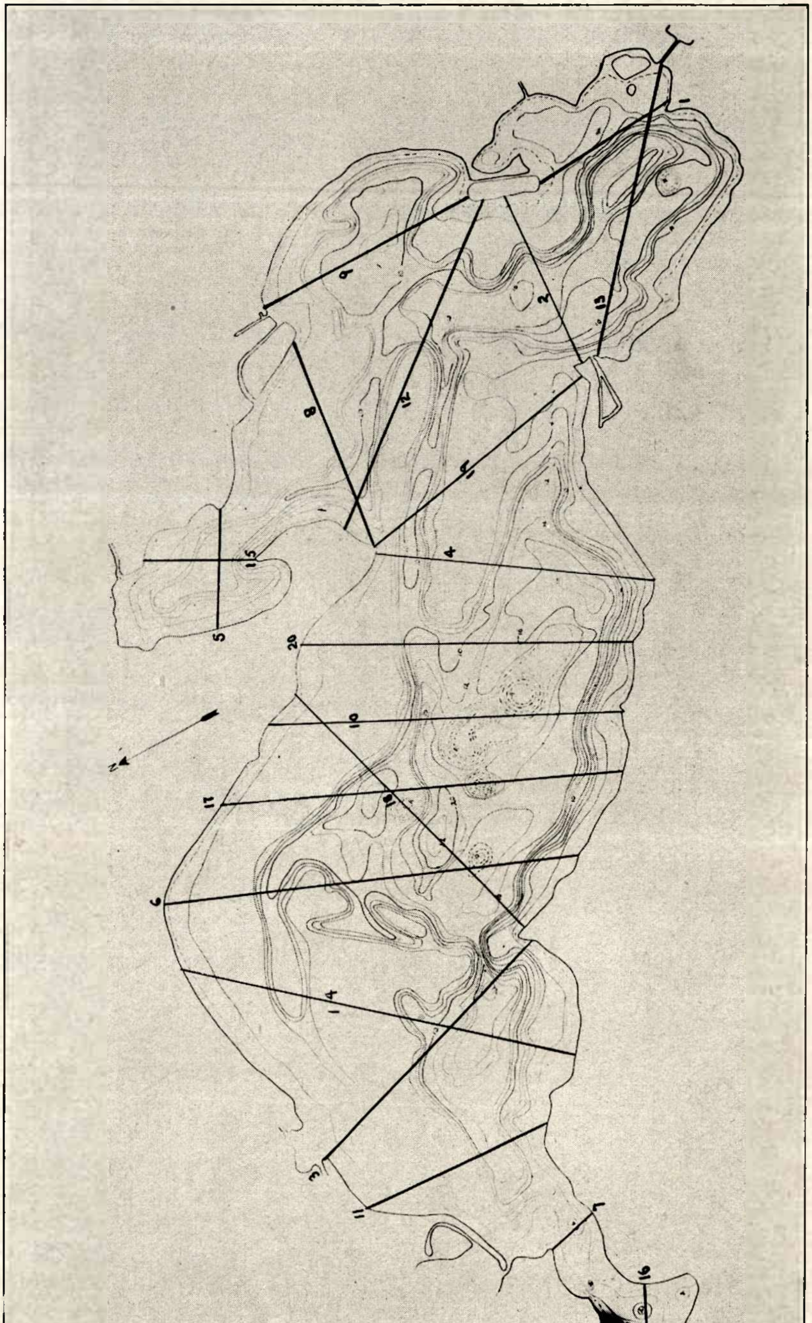


PLATE V. Lake map showing the lines along which the deep water collections were made. The points of intersections of these lines and the contours of 3 meters and deeper are the "deep" water stations.

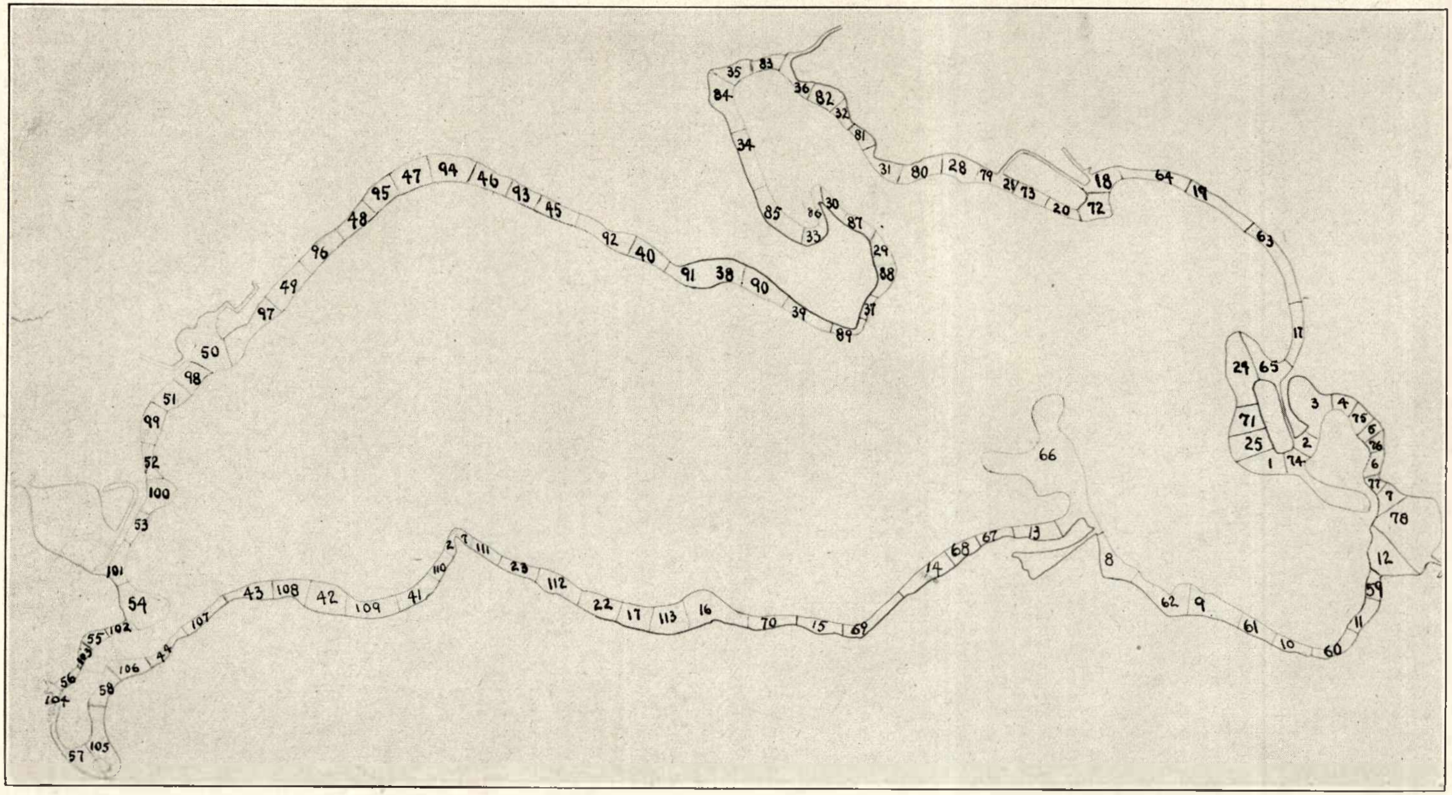


PLATE VI. The littoral stations. This plate in connection with table 3 shows where the maximum of each littoral form occurred.

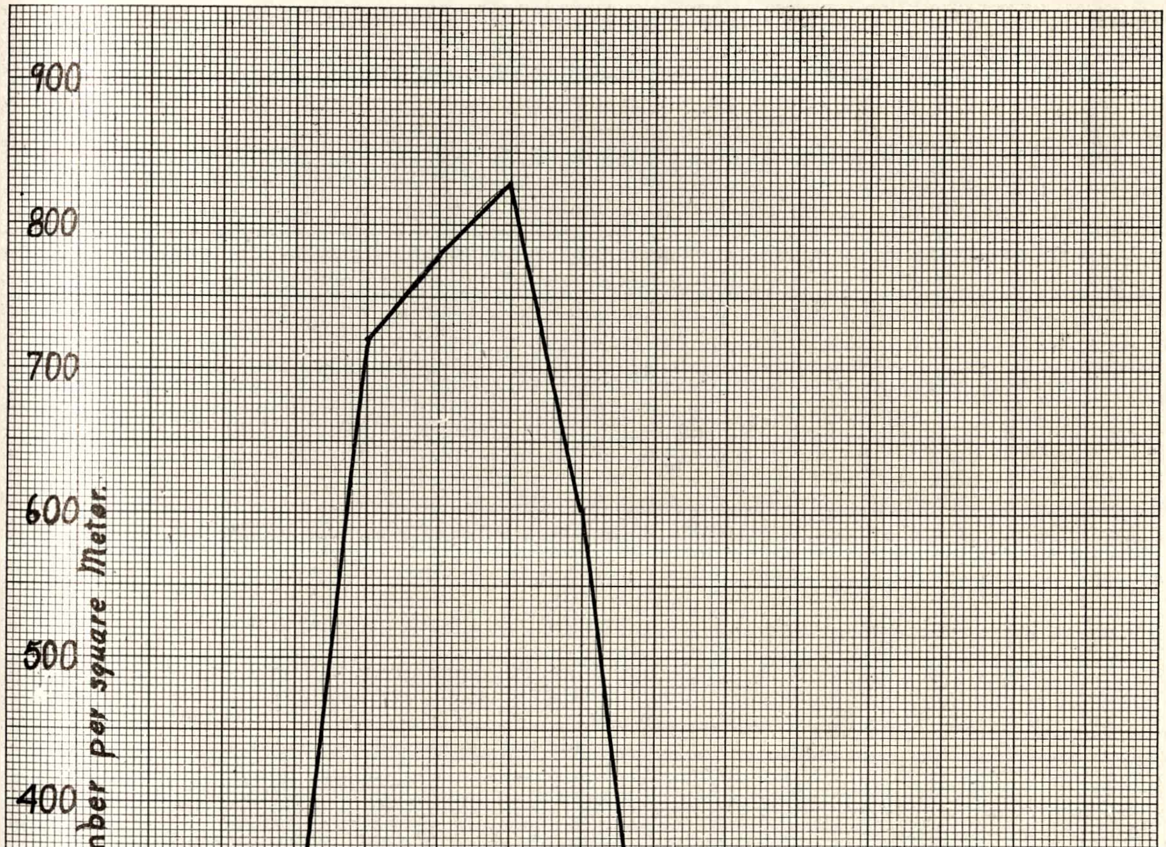


PLATE VII. Depth distribution of Chironomus tentans and other Chironomidae.

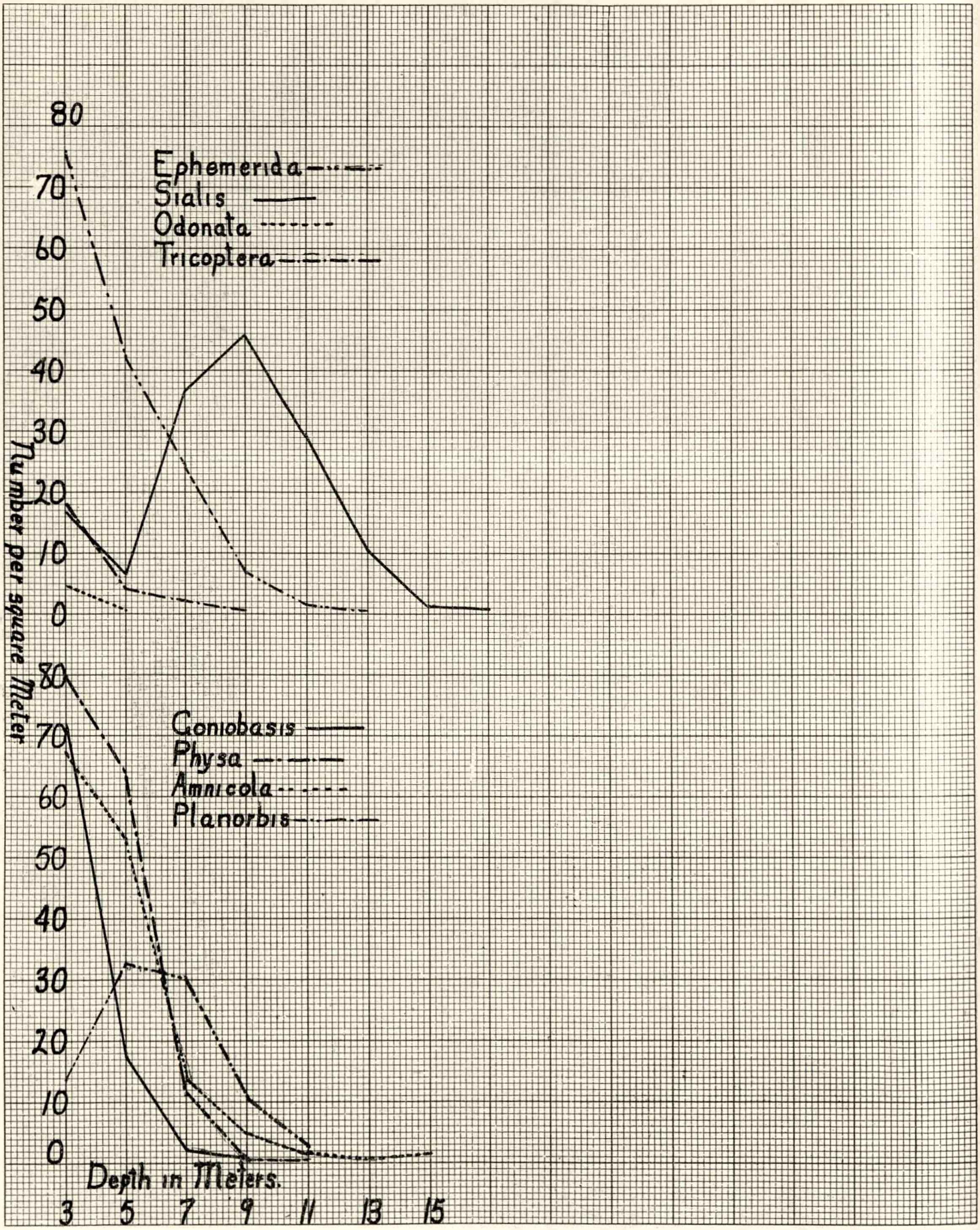


PLATE VIII. Depth distribution. Above four common groups of insect larve. Below: four common genera of snails.

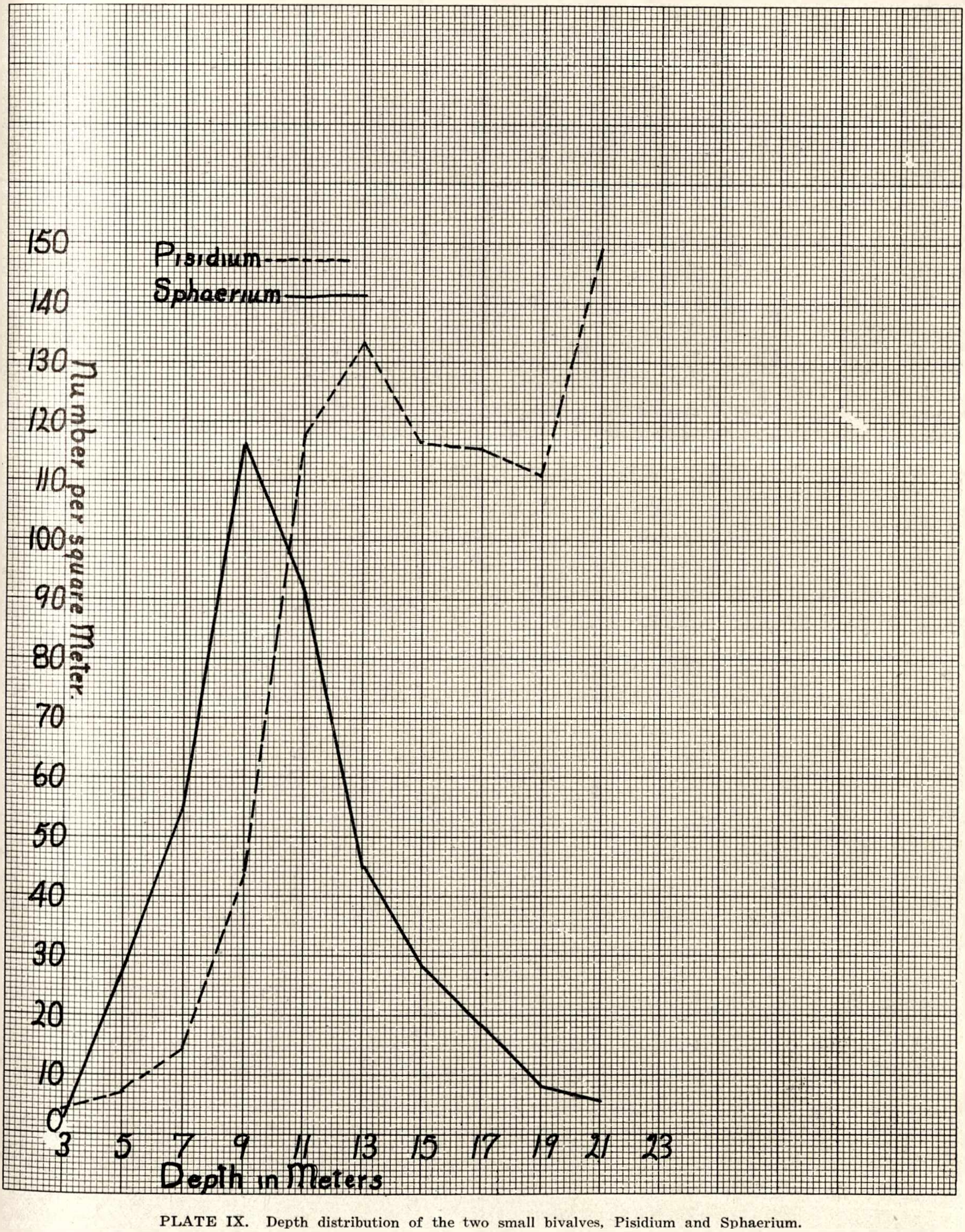


PLATE IX. Depth distribution of the two small bivalves, Pisidium and Sphaerium.